Radiation reaction to the motion of a point particle in Kerr spcetime(Digest_要約)

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In this thesis, we study the inspiral motion of a particle in the more massive Kerr black hole spacetime subjected to the radiation reaction, which is an extreme mass ratio limit of the binary system and a promising candidate for the source of gravitational radiation. Toward the accurate theoretical model of the binary dynamics to extract the meaningful information from the emitted gravitational waves, we revisit the radiation reaction to the inspiral motion in Kerr spacetime and describe this system in the language of a Hamilton system. In this framework, instead of directly integrating the equation of the motion with gravitational self-forces, the orbit of the particle can be described by the Hamilton's equations of the geodesic motion on an effective spacetime.

The first objective of this thesis is to systematically extract the solution of Hamilton's equations that is relevant to the orbital evolution for a long time period. Relying on the action-angle variables and using the two timescale ansatz, we see that the secular changes of both action and angle variables are characterized by only differentials of a single scalar quantity: the long time averaged value of the interaction Hamiltonian. In addition, at the leading order in the mass ratio of the binary, we show that these secular changes are expressed in the gauge invariant manner. The results of the two timescale analysis also reveal that the leading order dynamics of the inspiral motion are equivalently described by the secular change of the constants of motion of Kerr geodesic, *i.e.*, the energy, azimuthal angular momentum and the Carter constant, which is consistent with previous expectations in the literatures. Thanks to the systematic framework of the two timescale analysis, it turns out that the averaged value of the second order interaction Hamiltonian in the mass ratio of the binary is inevitable in computing the sub-leading correction to the inspiral motion.

The second objective of this thesis is to establish a practical scheme to extract the knowledge obtained from the two timescale analysis. As a first application, we derive a simple expression to compute the change rate of the constants of motion of Kerr geodesic in the linear black hole perturbation theory. The principal problem is to find a practical formula to compute the change rate of the Carter constant, which does not admit the conserved current composed of the perturbation field. Although it has been shown that the averaged rate of change of the Carter constant can be given by a simple formula, when there exists a simultaneous turning point of the radial and polar oscillations, this requirement prohibits us to apply the formula when the inspiraling orbit

crosses a resonance point, where the frequencies of the radial and polar orbital oscillations are in a rational ratio, because one cannot find a simultaneous turning point at the resonance point in general. Despite these difficulties at the resonance point, we present another simple method to evaluate the averaged rate of change of the Carter constant with resonance.

Another application is to establish a way to read out the conserved part of the orbital dynamics, which is responsible for the sub-leading correction to the inspiral motion on Kerr spacetime. For this purpose, we construct the conserved system where the secular growth of the action variables are negligible at least the leading order of the binary mass ratio, and disentangle the dissipative effects of the inspiral motion associated with the gravitational wave emission. Since the periodicity of the Kerr geodesic is not destroyed in the conserved system, we focus on the frequency shift of the inner most stable spherical orbit, say, inclined circular orbit in the Kerr spacetime on the verge of its separatrix between the stable and unstable bound orbit, and derive a formula to compute the frequency shift due to the presence of the interaction Hamiltonian.

All of these results illuminates the powerfulness of the Hamilton mechanics approach in handling the radiation reaction to the motion in Kerr spacetime.